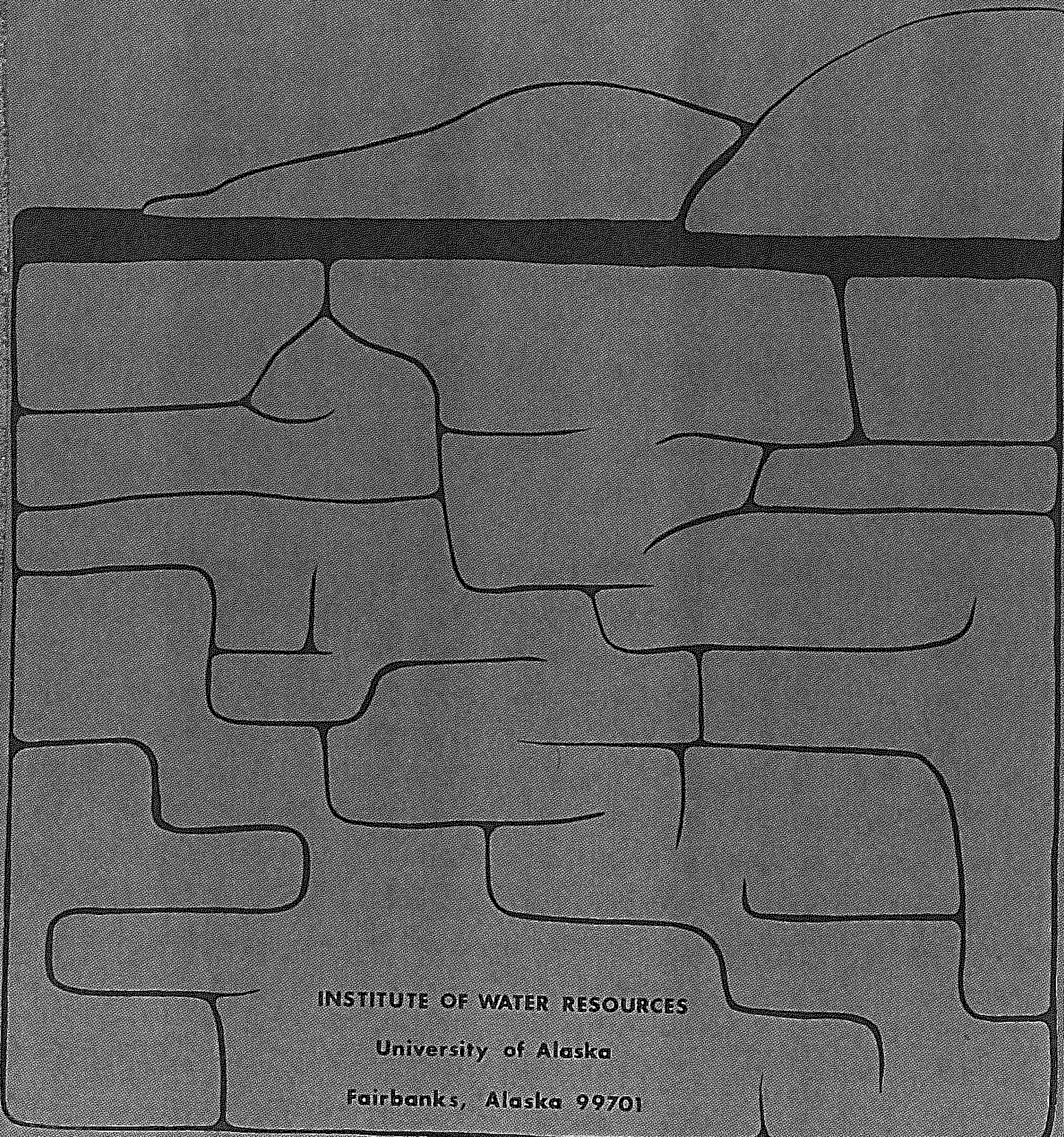
LAND DISPOSAL OF SECONDARY LAGOON EFFLUENTS (PILOT PROJECT)



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LAND DISPOSAL OF SECONDARY

LAGOON EFFLUENTS

(PILOT PROJECT)

Land disposal of secondary lagoon effluents (pilot project)
Daniel W. Smith

Study Report

by

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INTRODUCTION

The US Environmental Protection Agency has established standards for the quality of municipal wastewater which may be discharged to the nation's waterways after July 1, 1977. Basically these state that all sewage treatment plants discharging municipal waste will provide a minimum of secondary treatment. In 1973, secondary treatment was defined as meeting the following criteria:

(a). Biochemical oxygen demand (five-day). The arithmetic mean of the values for effluent samples collected in a period of 30 consecutive days shall not exceed 30 milligrams per liter.

(b). Suspended solids. The arithmetic mean of the value for effluent samples collected in a period of 30 consecutive days shall not exceed 30 milligrams per liter.

(c) Fecal coliform bacteria. The geometric mean of the value for effluent samples collected in a period of 30 consecutive days shall not exceed 200 per 100 milliliters. (EPA, 1973).

When considering remote or very low density locations, one immediately questions the validity of some of these regulations. However, once they are assumed fixed, the problem becomes one of meeting the effluent requirements at a reasonable cost. The regulations definitely call for a better quality effluent than is normally obtained using conventional secondary lagoons, one of the most commonly used systems in remote and low-density areas.

After the promulgation of these regulations, several engineers, researchers, and administrators began to examine the lagoon systems and methods of upgrading the quality of the discharge.

Another approach taken was to look at methods of disposal of the lagoon effluent which would not place it directly in a stream. In the event some of the effluent does reach a stream its quality should meet or exceed the established limits. Many projects and evaluations have been conducted with this alternative in mind (Ehlert, 1973; EPA, 1973; Hartigan, 1974; Malhota and Myers, 1974; Middlebrooks, *et al.*, 1974; Pettit and Whelston, 1973; Pound and Crites, 1973; Reed and Buzzell, 1974; Sopper, 1974; Sullivan, *et al.*, 1973).

This project report presents the results of a pilot project directed toward an initial examination of land disposal as a means of improving the quality of lagoon effluents under the climatological and soil conditions found in the interior of Alaska.

OBJECTIVES

The principle objective of this effort was to assist the US Army, Cold Regions Research and Engineering Laboratory, in conducting a pilot land disposal project in the interior region of Alaska. This project was a preliminary investigation of the feasibility of land disposal of secondary effluent from an aerated lagoon during the summer months. The hope was to examine the possible use of this technique to meet 1977 standards for the quality of secondary effluents.

STUDY SITE

An area near the Eielson Air Force Base wastewater treatment lagoon was selected for the field project by the CRREL project directors. The lagoon is a newly constructed, four stage lagoon using coarse bubble diffusers. The facility is manned by civilians and military personnel.

The test cells were located on the north side of the lagoon system. It is very likely that the soil of the test cells had been distributed during construction of the lagoon (Figure 1). The equipment used included a submersible pump which was placed in the second stage lagoon and 1-inch PVC pipe which was laid across the roadway, down the lagoon embankment, and to each of three 25-foot square test cells. A fourth 25-foot square area was set aside to function as a control area. Each test cell was loaded individually on separate days. Liquid was pumped from the lagoon through a ball valve to control the rate of application, then through a flow meter and finally through the distribution nozzle onto the test cell. Each nozzle was adjusted such that the area of cover was a circle 20 feet in diameter located in the center of the test cell.

In each test cell, two lysimeters were installed, one at a depth of 6 inches and the other at 18 inches. These were installed by carefully removing soil to the necessary depth, placing the unit, and carefully backfilling. These lysimeter were designed and installed by CRREL personnel. One lysimeter was located on each side of the spray nozzle along the axis of the test cells. See Figure 2 for a general diagram of the lysimeters used for sample collection. Samples were collected by applying a vacuum to a sample bottle which was, in turn, attached to the sample tube, and drawing the sample from the collection device.

Samples collected from the lysimeters were divided into three types of samples as follows:

1. a portion for BOD's and suspended solids analyses

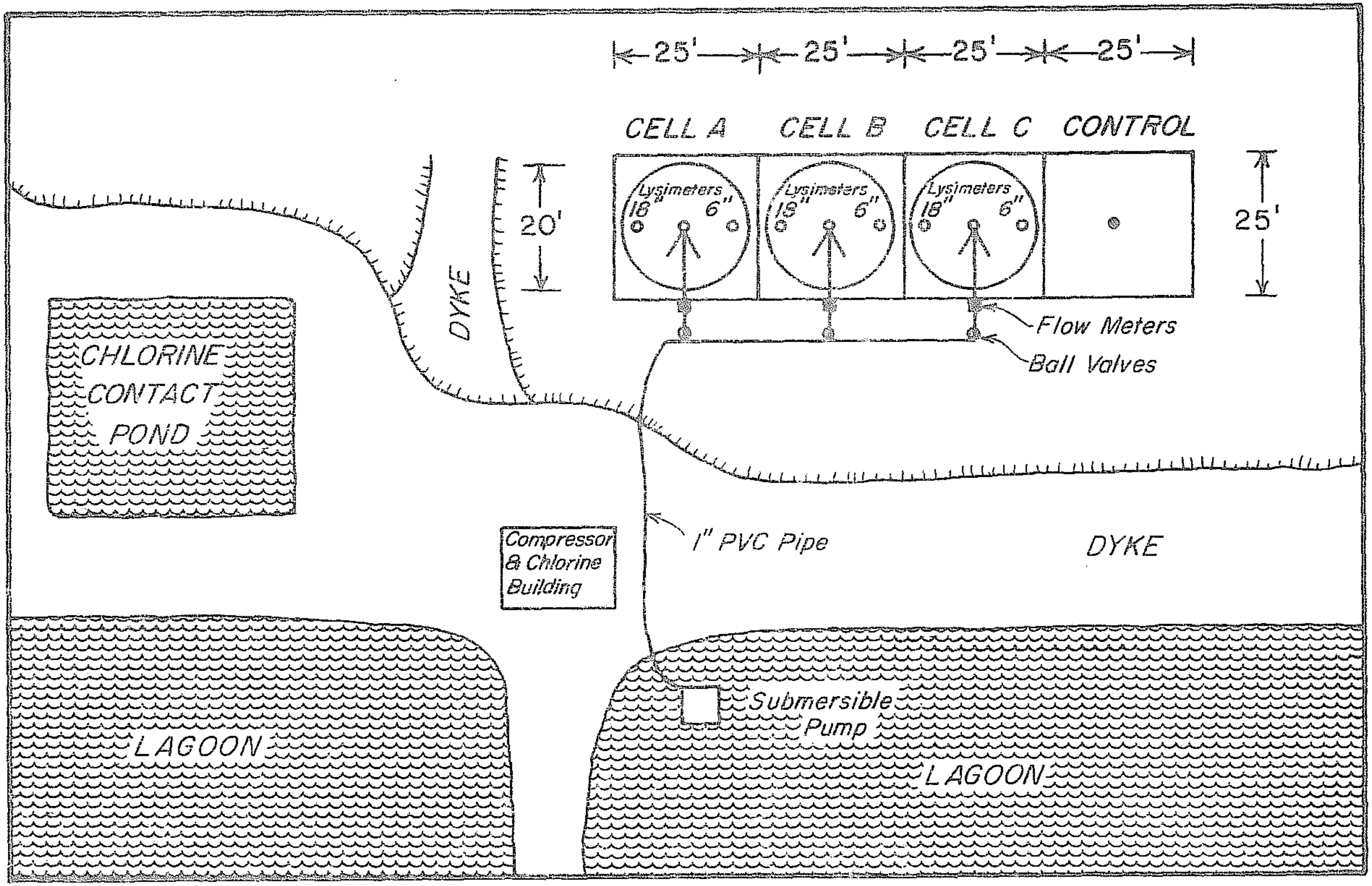

Figure 1: General Plan of Study Site near the Wastewater Treatment Lagoons at Eielson Air Force Base.

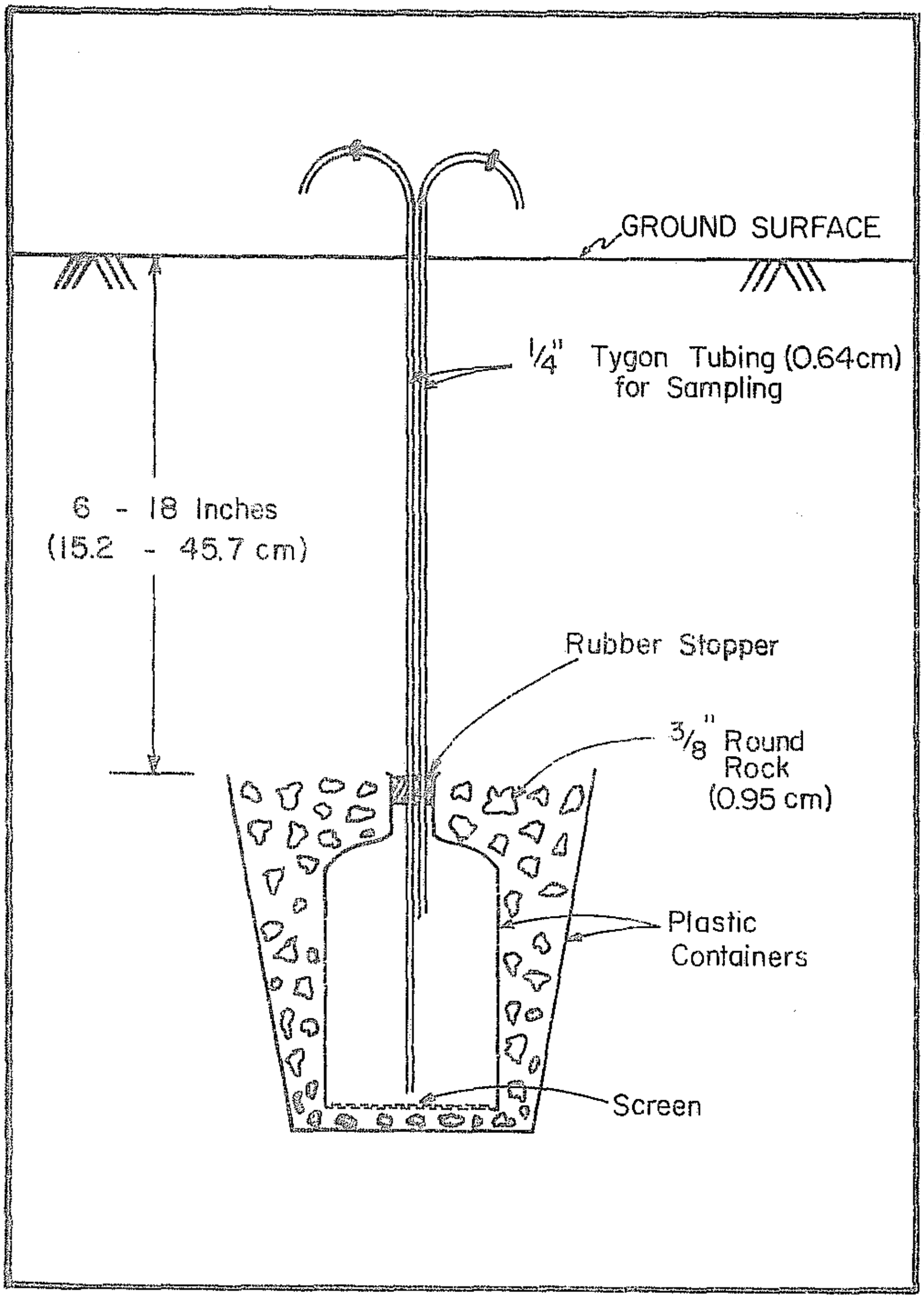

Figure 2: Lysimeter for collection of Percolating Wastewater.

2. a 50 milliliter portion which was immediately frozen for nitrate-nitrite and ammonia analyses

3. a 10 milliliter portion which was treated with 2 or 3 drops of nitric acid for TOC analysis.

Due to problems in the laboratory and the amount of samples available it was not possible to run organic or total nitrogen or phosphate analyses.

METHODS

Data conducted during the project fall into several categories: flow; soil tests; and chemical, physical, and bacterial analyses. Flow measurements were made by taking consecutive readings on a Badger flow meter.

Soil tests included wet and dry sieve analyses, moisture content, and percent volatile solids. The last two tests were performed following standard techniques. The sieve analyses were run using standard U.S. sieves at the Alaska Department of Highways Test Laboratory. Percolation tests were conducted by the CRREL project staff.

The chemical analyses include biochemical oxygen demand, five-day, nitrate-nitrite, ammonia, and total organic carbon. The BOD_5 tests were conducted following the procedure in *Standard Methods* (APHA, AWWA, WPCF, 1971) by the staff of the Eielson Wastewater Treatment Plant.

The nitrate-nitrite and ammonia tests were conducted using the procedures specified for the Auto Analyzer. The Total Organic Carbon (TOC) analyses were conducted using a Beckman Analyzer at the Arctic Environmental Research Laboratory.

Physical measurements of suspended solids and temperature were conducted by the staff of the Eielson Treatment Plant. The bacterial analyses were also conducted by the Eielson Treatment Plant staff.

RESULTS

Four aspects of the total land disposal system are of interest. First is the type and characteristics of the soil receiving the wastewater loading. In order to define the general characteristics of the soil being used, wet and dry sieve analyses were conducted. These showed that the soil could be classified as a silt. The results of the sieve analyses are given in Tables I, II and III for Cells A, B, and C, respectively.

To assist in the evaluation of the soil, moisture content and volatile solids analyses were conducted on soil samples collected before wastewater loading was started. This information also appears in Tables I, II, and III. At the end of the loading period in late September, similar soil samples were collected and volatile solids analyses were conducted. The results of these analyses are shown in Table IV. The results of the percolation tests were not available at the time of this report.

The second aspect of the disposal system which warrants consideration is the loading rate. Each of the three cells was to have a different amount of lagoon effluent applied to it each week. The weekly loads are presented in Table V. The data is presented in total gallons applied, gallons per square foot, and inches of wastewater per square foot. It should be noted that Cell A received an average loading of 3.16 inches per square foot per week; Cell B, an average loading of 5.09 inches per square foot per week; and Cell C, an average loading of 7.16 inches per square foot per week.

The next aspect requiring consideration is the weather conditions experienced during the test period. The weather information for the 24 hour period between loading of the test site and sample collection is also presented in Table V. This table also gives the amount of sample that was collected on each occasion. It is noted that the amount of sample collected bore no discernible relationship to the amount of precipitation which occurred during the 24-hour loading period. Other weather information, such as wind direction, temperature, and relative humidity, is given in Table V.

TABLE I

Soil Analyses - Cell A

SAMPLE IDENTIFICATION	1 to 6 Inches	6 to 12 Inches
Sample weight (gm)	438.5	493.6
Percent moisture (wet basis)	11.2	19.0
Percent volatile solids (dry basis)	1.58	2.29

Sieve Number	Sieve Opening (m)	Wt. Soil Retained (gm)	Percent Retained	Sum Percent Retained	Percent Finer	Wt. Soil Retained (gm)	Percent Retained	Sum Percent Retained	Percent Finer
4	4.75	51.8	11.81	11.81	88.19	12.1	2.45	2.45	97.55
10	2.0	9.6	2.10	14.0	86.00	2.0	0.41	2.86	97.14
16	1.19	1.8	0.41	14.41	85.59	0.7	0.14	3.00	97.00
30	0.6	2.2	0.50	14.91	85.09	0.9	0.18	3.18	96.92
40	0.425	3.5	0.80	15.71	84.29	0.8	0.16	3.34	96.66
50	0.3	14.9	3.40	19.11	80 89	2.5	0.51	3.85	96.15
Pan	165.5	37.74	56.85	43.15	159.4	32.29	36.14		
Total		249.3				178.4			
200 (wet)		249.6	56.9		43.1	178.3	36.12		60.01
Error		0.2				0.1			

TABLE II

Soil Analyses - Cell B

SAMPLE IDENTIFICATION	1 to 6 inches	6 to 12 inches
Sample Weight (gm)	500.3	443.9
Percent Moisture (Wet Basis)	22.1	19.6
Percent Volatile Solids (Dry Basis)	4.59	4.12

Sieve Number	Sieve Opening (mm)	Wt. Soil Retained (gm)	Percent Retained	Sum Percent Retained	Percent Finer	Wt. Soil Retained (gm)	Percent Retained	Sum Percent Retained	Percent Finer
4	4.75		Sample Lost			55.4	12.48	12.48	87.52
10	2.0					4.4	0.99	13.47	86.53
16	1.19					1.8	0.41	13.88	86.12
30	0.6					3.2	0.72	14.60	85.4
40	0.425					3.3	0.74	15.34	84.66
50	0.3					8.1	1.82	17.16	82.84
Pan						99.2	22.35	39.51	
Total						175.4			
200 (wet)						174.9	39 4		60.6
Error						0.5			

TABLE III

Soil Analyses - Cell C

SAMPLE IDENTIFICATION	1 to 6 inches	6 to 12 inches
Sample Weight (gm)	428.7	420.1
Percent Moisture (wet basis)	25.4	19.3
Percent Volatile Solids (dry basis)	7.37	3.21

Sieve Number	Sieve Opening (mm)	Wt. Soil Retained (gm)	Percent Retained	Sum Percent Retained	Percent Finer	Wt. Soil Retained (gm)	Percent Retained	Sum Percent Retained	Percent Finer
4	4.75	17.2	4.01	4.01	95.99	15.4	3.67	3.67	96.33
10	2.0	2.9	0.68	4.69	95.31	0.7	0.17	3.84	96.16
16	1.19	1.4	0.33	5.02	94.98	0.5	0.12	3.96	96.04
30	0.6	2.6	0.61	5.63	94.37	1.3	0.31	4.27	95.73
40	0.425	2.7	0.63	6.26	93.74	1.1	0.26	4.53	95.47
50	0.3	6.2	1.45	7.71	92.29	2.4	0.57	5.1	94.90
Pan		93.7	21.86	29.57		112.7	26.83	31.93	
Total		126.7				133.4			
200 (wet)	126.4	29.48		70.52		134.1	31.92		68.08
Error	0.3					0.7			

TABLE IV
PERCENT VOLATILE SOLIDS
OF SAMPLES COLLECTED
SEPTEMBER 26, 1974

Sample Identification		Volatile Solids (Percent)
Cell	Depth (inch cm)	
A	3	3.95
A	6	2.37
A	9	3.37
B	3	4.58
B	6	2.80
B	9	4.12
C	3	1.58
C	6	6.17
C	9	1.60
Control	3	1.71
Control	6	0.85
Control	9	1.73

TABLE V

BASIS DATA ON SITE LOADING AND SITE WEATHER CONDITIONS

Date	LOADING				SAMPLE	WEATHER						
	Cell	Gallons	Gal/sq. ft.	inches/sq. ft.	Volume (6 inch)	precip. (in)	Temperature Max.	Temperature Min.	Temperature Ave.	Wind Dir.	Wind Knots	Relative Humidity
July 29	A	580.5	1.85	2.96	.885	0	80	57	68	SE	4	33
July 30	B	994.8	3.17	5.08	2.0	10	65	54	57	V	2	58
July 31	C	1412.4	4.50	7.21	0.6	0	76	55	65	V	3	41
Aug. 5	A	581.9	1.85	2.96	0.03	0	77	45	61	WNW	5	42
Aug. 6	C	1309.3	4.17	6.69	0.1	0	79	48	63	SW	3	34
Aug. 7	B	1018.8	3.24	5.20	1.2	T	70	58	64	V	2	52
Aug. 12	A	581.4	1.85	2.96	none	0.23	62	48	55	WSW	2	63
Aug. 13	B	987.8	3.14	5.04	1.8	0.13	62	56	59	SW	6	72
Aug. 14	C	1386.1	4.41	7.08	0.005	0.02	74	54	64	S	10	50
Aug. 19	A	608.3	1.94	3.11	0.4	0.7	58	45	55	E	15	84
Aug. 20	C	1394.9	4.44	7.12	0.27	T	60	43	55	ESE	5	74
Aug. 21	B	1008.1	3.21	5.15	2.0	0	52	36	44	ENE	10	50
Aug. 27	A	683.7	2.18	3.49	0.6	0.2	58	40	51	SW	9	47
Aug. 28	B	990.2	3.15	5.06	1.8	0.13	77	51	64	SSW	4	83
Aug. 29	C	1399.6	4.46	7.15	0.1	0	77	43	60	WNW	3	65
Sept. 10	C	1514.3	4.82	7.73	1.4	0	67	31	48	NE	1	29
Sept. 11	B	999.3	3.18	5.10	1.8	T	64	37	51	SE	4	35
Sept. 12	A	658.3	2.10	3.36	0.8	0	65	45	55	S	13	40
Sept. 17	A	662.5	2.11	3.38	1.2	0	63	33	48	N	7	45
Sept. 18	B	1011.2	3.22	5.16	1.2	0	62	30	41	NNW	9	48
Sept. 19	C	1408.0	4.48	7.19	0.8	0	58	30	40	SE	16	42
Sept. 24	C	1397.0	4.45	7.13	0.06	0.02	64	43	54	N	7	69
Sept. 25	B	967.6	3.08	4.94	1.8	0.15	46	38	42	W	8	67
Sept. 26	A	592.4	1.89	3.03	0.06	0.03	49	38	44	N	7	60

The fourth aspect of the land disposal system and, in many respects the most important, is, does the treatment system provide the quality changes in the wastewater that are desired? To help prepare a preliminary answer to this question and within the financial constraints of the project the following parameters were examined: BOD_5, suspended solids, pH, TOC, nitrate plus nitrite, ammonia, and fecal coliform. The analyses were run as regularly as possible. The availability of sufficient sample from the lysimeters was the most serious constraint. The results of the analyses are presented in Table VI.

It is important to note that only two samples were obtained from the lysimeters at 18 inches. Both of these samples were very small and complete analysis was not possible. One sample was from Cell B on July 31, 1974. The other sample was from Cell C on August 1, 1974. The results of the analyses on these two samples are given at the bottom of Table VI.

The reason for the lack of sample from the lysimeters that were 18 inches deep may be due to one or a combination of the following:

1. lack of water reaching that depth
2. failure of the catch containers which allowed the samples to leak out
3. improper installation.

The limited information available does not provide an answer to this problem

TABLE VI

RESULTS OF ANALYSES OF SAMPLES FROM APPLIED WASTEWATER AND 6" DEPTH LYSIMETER

Week	Date	Sample pt.	BOD (mg/l)	Susp. Sol. (mg/l)	pH (Phenol Red D)	TOC (mg/l)	Nitrogen $NO_2 + NO_3$ (mg/l)	NH_3 (mg/l)	Fecal Coliform per/100 ml
1	7/29	influent	10 mg/l	65 mg/l	7.2	45	0.01	>10	-
	7/29	Cell A	3.6	10	7.0	15	3.14	0.81	-
	7/31	B	6.8	8	6.8	34	1.50	0.48	-
	8/1	C	-	5	7.0	36	7.32	0.46	-
2	8/5	influent	-	54	7.2	32	0	>10	
	8/5	Cell A	only 30 ml of sample obtained			20	-	-	-
	8/6	C	only 100 ml of sample obtained			30	5.5	-	-
	8/7	B	-	4 mg/l	7.2	29	>10	0.38	-
3	8/14	B	1.8	4	6.8	23	5.8	0.49	TNC approx. 1500
4	8/20	influent	15.0	58	7.2	-	-	-	-
	8/20	Cell A	-	3	7.0	18	>10	0.37	880
	8/21	C	-	6	7.0	-	9.10	0.11	-
	8/22	B	-	3	6.8	-	-	-	-
5	8/27	influent	-	42	7.0	-	-	-	-
	8/27	Cell A	-	5	7.0	-	-	-	40
	8/28	B	-	3	6.8	-	-	-	210
	8/29	C	-	-	-	18	7.33	0.26	-
6	9/10	influent	-	51	7.2	53	0	>10	-
	9/10	C	-	28	7.2	21	7.96	0.13	-
	9/11	B	-	2	6.8	10	4.36	0.44	1010
	9/12	A	-	8	7.0	16	3.14	0.81	210
7	9/17	influent	153	128	7.2	90	0.04	>10	-
	9/17	A	-	4	7.0	13	>10	0.22	-
	9/18	B	4.7	2	6.8	-	4.02	0.43	36000
	9/19	C	-	-	7.0	20	>10	0.18	-
8	9/24	influent	-	54	7.2	48	0.04	>10	-
	9/24	C	-	-	-	13	9.15	0.17	-
	9/25	B	-	3	6.8	27	5.97	0.68	13800
	9/26	A	-	-	-	47	> 10	0.22	-
18 inches deep lysimeter									
	7/31	B	-	-	-	14	0.65	0.33	-
	8/1	C	-	-	-	16	-	-	-

DISCUSSION

Two items are of concern when considering land disposal of wastes: 1) Will the system remove the parameters of concern, and 2) What are the limits on the loading rate? These two topics are discussed below in detail.

REMOVAL EFFICIENCY

In all cases the samples collected from the sampler 6 inches deep met effluent requirements for suspended solids (SS) and biochemical oxygen demand (BOD) concentrations in the effluent. Similarly, pH values were within the required range. Fecal coliform values were higher than effluent requirements. The average, high, and low values of each parameter are reported along with the number of samples tested, in Table VII.

The pH values of the wastewater applied were within the acceptable range according to the EPA regulations. No significant change in pH was observed as the water percolated through the soil.

Material causing a biochemical oxygen demand may be either particulate, colloidal or soluble. The substantial changes in concentration indicate the removal may have been due to the filtering out of particulates. However, biological activity in the soil probably influenced the results greatly. It must be noted that the number of samples and the period of time the system was in operation were limited. This definitely limits the value of the information collected. It is worth noting that when the lagoon began to experience its fall failure, Cell B was still showing effective removal of BOD.

Suspended solids loading exceeded the recommended effluent levels in every sample collected. (Note that the material being applied was coming from the second stage of a four stage lagoon.) Although all samples collected from the lysimeters met discharge requirements, it is important to note that the sample collected from Cell C on September 10,

TABLE VII

SUMMARY OF RESULTS

Constituents	Wastewater Applied	Cell A	Cell B	Cell C
BOD_5, mg/l				
Mean	59.3	3.6	4.1	-
Maximum	153	-	6.8	-
Minimum	10	-	1.8	-
Number	3	1	3	-
Total Organic Carbon, mg/l as C				
Mean	53.6	21.5	24.6	23.0
Maximum	90	47	34	36
Minimum	32	13	10	13
Number	5	6	5	6
Suspended Solids, mg/l				
Mean	64.6	6.0	3.6	13.0
Maximum	128	10	8	28
Minimum	42	3	2	5
Number	7	5	8	3
Nitrate-Nitrite, mg/l as N				
Mean	0.02	7.26*	5.28	8.48*
Maximum	0.04	>10	5.97	>10
Minimum	0.0	3.14	1.50	7.32
Number	5	5	5	6
Ammonia, mg/l as N				
Mean	>10	0.34	0.48	0.22
Maximum	>10	0.81	0.68	0.46
Minimum	>10	0.22	0.38	0.11
Number	5	5	6	6
pH				
Mean	7.2	7.0	6.8	7.05
Maximum	7.2	7.0	7.0	7.2
Minimum	7.0	7.0	6.8	7.0
Number	7	5	8	4
F. coli/100 ml				
Mean	-	377	10504	-
Maximum	-	880	36000	-
Minimum	-	40	210	-
Number	0	3	5	0

*Average of all values

1974 was approaching the suspended solids limit (See Figure 3) No samples were collected from Cell C later in the year. This cell, receiving an average loading of 7.16 inches a week, may have been reaching its limit for the season. This speculation cannot be confirmed or denied from the limited data.

The fecal coliform data reported here is the most distressing of the parameters tested. The mean values of three samples from Cell A and five samples from Cell B exceeded the 1977 requirements for wastewater discharges. Unfortunately no analyses were made of the fecal coliform counts in the wastewater applied. Another possible source of the problem was that during the course of the study the equipment used by the Eielson Air Base staff for fecal coliform analysis was in the process of being set up. This may have led to inaccuracies in the results. This parameter warrants considerably more study before wide use of land disposal is made in Alaska.

Other parameters examined include total organic carbon (TOC), nitrate plus nitrite and ammonia (See Figure 3). The TOC data shows an average reduction of 58 percent. This fact along with the BOD removal data indicates that much of the organic matter being removed by filtering through the soil was the biodegradable fraction and that the nonbiodegradable fraction may have been finer and not readily removed by the soil matrix

Ammonia concentrations in the wastewater applied to the land exceeded 10 mg/l in all five samples tested. However, in the samples collected from the lysimeters 6 inches down, the average concentration was below 0.5 mg/l as nitrogen. The results of the nitrate plus nitrite measurements showed the opposite pattern. The wastewater applied had an average concentration of 0.02 mg/l. The samples collected at the 6 inch depth had average concentrations from 5.28 to 8.48 mg/l of nitrate plus nitrite as nitrogen.

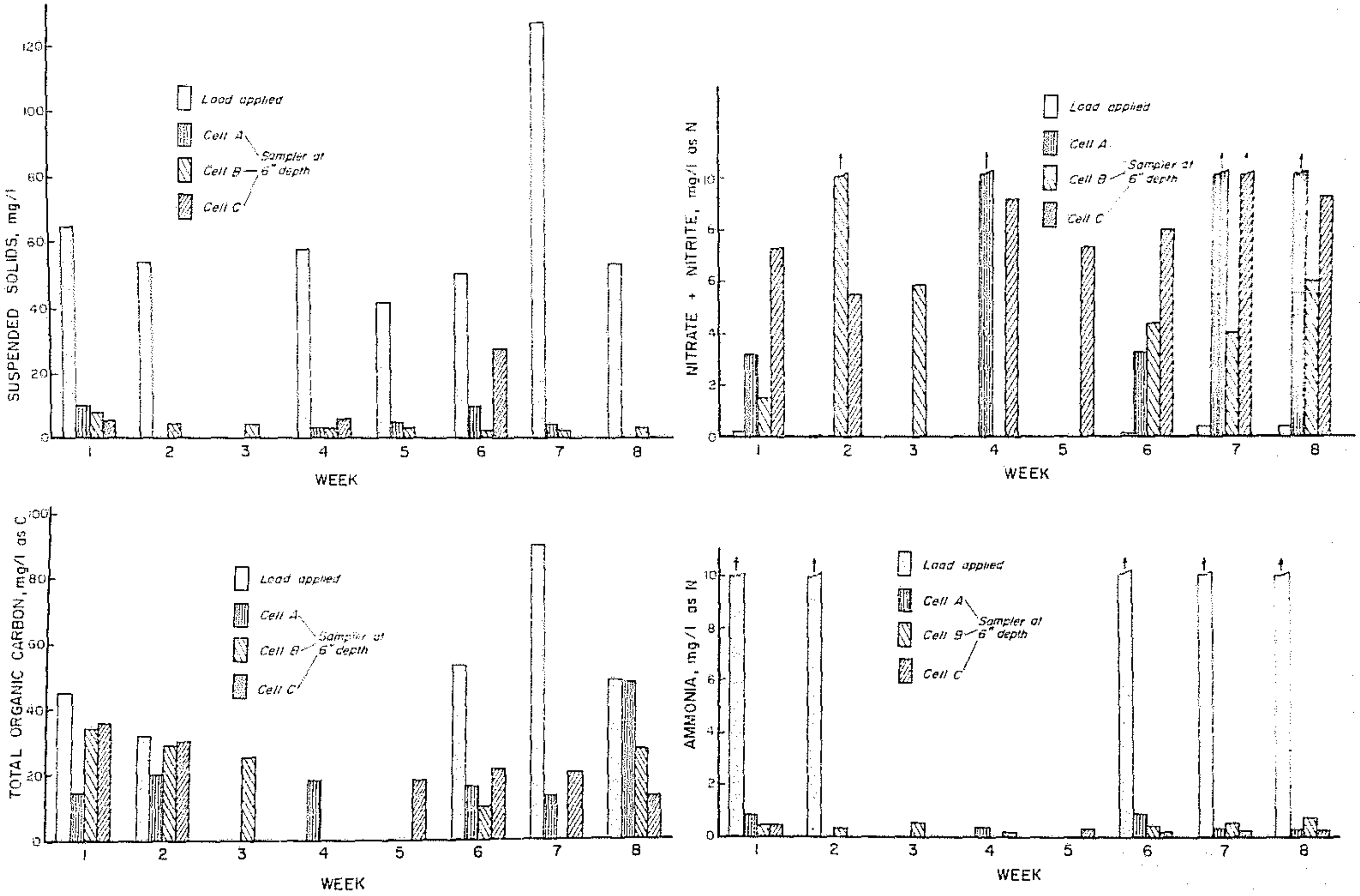

Figure 3: Results of analyses on samples collected at a depth of 6 inches.

LOADING RATES

With the data collected, little difference could be detected between the three test cells. The suspended solids concentrations found in the samples collected from Cell C at 6 inches depth were the only indication of the higher loadings being applied.

The major problems with soil disposal in the interior of Alaska are: (a) the very short period available for soil loading and (b) the low porosity of the silty soil.

In the Fairbanks area, a maximum of 4 to 5 months of the year would be suitable for land disposal of wastewater. The remaining 7 to 8 months of the year would require another means of handling the discharge be used. One alternative is to hold the wastewater during the cold months and apply it to the soil during the summer. Another approach which could be applied for algal suspended solids control is to limit use of the land disposal efforts to periods of high algae population. The remainder of the year the system would function as an aerated lagoon.

Another approach to land disposal in areas of intermittently frozen soils is the use of infiltration lagoons during winter periods. Such a system would allow excess wastewater to percolate into unfrozen lower soils in the winter. A conventional land disposal system could be used during the summer. This technique would require the location of the proper subsurface soils and drainage patterns to be feasible.

Nutrient deficiency and possible water deficiency appear to be serious problems in many interior Alaskan soils. Precipitation averages 11.2 inches in the Fairbanks area. About half of the precipitation arrives during the growing season; the remainder is lost to evaporation and runoff. Both of these environmental deficiencies could be supplemented by a properly planned and operated land disposal system. The degree and form of stimulation of the existing ecosystems warrant close study.

The low rate of percolation through the surface loess found in parts of interior Alaska may have serious consequences if not properly considered when designing a land disposal system. The results of percolation tests may yield some valuable information as to acceptable loading rates. However, a surface ponding test may be a much more valuable indicator of the actual loading rates the surface material can transmit. As an example, the operator of this land disposal study reported some surface runoff from Cell A during the last 2 to 3 weeks of operation. This cell received the lowest loading rate of the three test areas. Minor ponding was reported on all cells during the last month of operation.

RECOMMENDATIONS

The results of this pilot project show that during the warm months of the year land disposal of lagoon effluents is a reasonable alternative for meeting current effluent quality requirements provided the proper soil conditions exist. Before wide application of this technique is made it is recommended that a minimum of one full scale system be established and tested much more extensively than the time and funding for this study allowed. The matters of fecal coliform migration through the local soils and the effects of the heavy loading on SS and BOD removal efficiency over a long period of time will require careful examination.

The use of the actual effluent from the lagoon must be examined. The effects of the nutrients in the effluent on the various types of vegetation and decomposers found in cold climates also warrants careful examination before extensive use of the technique is made.

In conclusion, the use of land disposal shows promise as a method of meeting the immediate effluent regulations. However, with this conclusion comes a host of very important questions which must be addressed. In order to have the necessary systems operational by the 1977 deadline, considerable immediate effort by a multidisciplinary group will be needed.

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